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Computer-Aided Design AND APPLICATIONS

Development of Parametric Modeling and Visualization Platform for Interior Design

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Abstract. The aim of this thesis is to investigate the development of a CAD-assisted parametric modeling and visualization teaching platform for interior design. Through the introduction of parametric modeling technology, the platform aims to realize the rapidity, precision, and flexibility of interior design. In the development of the platform, advanced virtual reality hardware devices are used to realize the visual display of interior design, which is integrated into the relevant teaching platform to enhance the teaching effect of the course further. This innovative integration allows students to understand the design concepts more intuitively through visualization and to interact and adjust in real time during the design process, thus enhancing their learning participation and design skills. The experimental results show that the platform can effectively improve the quality of teaching and provide students with a more intuitive and practical learning experience. The development of this platform not only conforms to the development direction of digital teaching but also promises to provide more diversified teaching methods and richer teaching resources.

Keywords: CAD-Assisted; Interior Design; Parameterization; Virtual Reality
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1 INTRODUCTION

Interior design is a comprehensive discipline that aims to create comfortable and beautiful living and working environments for people. With the development of society and technological progress, interior design continues to evolve iteratively, from traditional hand-drawing to computer-aided design (CAD), to today's parametric modeling and virtual reality (VR) technology, the application of a variety of tools and methods to make the design more flexible and diverse. A parametric design was initially applied. As an extension of architectural design, indoor space design is also influenced by parametric design methods due to the extensive use of computer-aided operations in architectural design. Parameterized interior designers analyze and summarize the constrained factors into corresponding constraint relationships and then use computer-aided design software to perform complex mathematical formula operations to generate a series of indoor space models that meet the constraint conditions. The parameterized design method greatly expands the ability of architectural designers to create complex forms. I believe that soon, parameterized interior space design will become the working mode of interior design. Parametric interior space design, as a new design method, has many advantages in computer-aided design, material processing, construction techniques, etc. However, for the design concept and process from processing to interior space, parametric interior space design lacks sufficient support in a theoretical framework. Bashabsheh et al. [1] focused on researching how to fully utilize the characteristics of parameterized indoor space to make design diverse and random, and strengthen the emotional, functional, and formal factors of indoor space in specific designs.

Berselli et al. [2] maintained the indoor architectural design parameter settings. It analyzed the ventilation area of 10% of the indoor floor area and the ground clearance distance of the air outlet 1.0 m from the floor. Explored the impact of three design parameters, namely building layout, building spacing, and building orientation, on the indoor natural ventilation effect. Using orthogonal tables to organize numerical simulation conditions, through orthogonal analysis of simulation results, comprehensively balance various indoor ventilation evaluation indicators, and obtain the optimal combination scheme of outdoor building design parameters. The plan is a staggered building layout, with a spacing coefficient of 0.7 between buildings and a building orientation that forms a 45 ° angle between the building's length and the incoming wind direction. Next, set the outdoor building design parameters based on the optimal outdoor combination plan. The influence of different indoor architectural design parameters on the indoor natural ventilation effect was investigated, and an orthogonal table was used to organize and simulate the indoor natural ventilation flow field under 9 working conditions with three parameters: different ventilation paths, ventilation area, and air outlet ground distance. Visual perception is one of the main ways for users to have an intuitive perception of indoor space. This has the strongest impact on subjective emotions compared to other senses, and its important position and role in the design process are self-evident. Design works will have a strong impact on human psychological activities and emotional experiences through the use of visual stimuli. Berseth et al. [3] analyzed the modeling advantages of parametric interior design at the human visual level using visual perception patterns. Summarized the specific methods for creating and selecting parameterized interior space design guided by the principles of visual psychology. Focusing on parameterized interior space design has the characteristics of randomness, unpredictability, high design efficiency, and the ability to be used for direct construction. CAD parametric design has brought new design approaches to architectural creation. For example, when dealing with specific architectural design schemes, the architect lists out some of the constraints on building construction one by one. This includes the analysis of building environmental conditions, pedestrian flow lines, structural construction factors, lighting environmental factors, airflow factors, sound field environmental factors, and ecological environmental performance. Dounas et al. [4] analyzed and summarized these constrained factors into corresponding constraint relationships. Then, complex mathematical formula operations can be performed using computer-aided design software to generate a series of building models that meet the constraints. The building models generated through this design method are extremely diverse, and the styles of the shapes are often unexpected. But at the same time, such a complex and ever-changing building model can also meet all the constraints listed by the designer. This parameterized design method greatly expands the ability of architects to create complex forms, while also improving their design efficiency.

Architectural design is no longer limited to meeting basic usage needs, but focuses more on optimizing building performance and improving the quality of life of residents. The interior design parameters of buildings, such as lighting, ventilation, temperature, humidity, etc., have a crucial impact on the comfort and energy efficiency of buildings. Therefore, how to scientifically and effectively utilize these design parameters has become an important research direction in the current field of architectural design. Elshafei et al. [5] extensively optimized the design parameters of building environments using genetic algorithms. The architectural layout also has a significant impact on the comfort and energy efficiency of the indoor environment. Through genetic algorithms, parameters such as room layout, corridor width, and staircase position of buildings can be optimized to achieve optimal indoor environmental effects and energy efficiency. Parameterized interior space design is a new and high-tech design method that utilizes computer-aided operations. In every step of the parameterized interior space design process, computer-aided calculations are involved. It has been increasingly accepted by designers with the outbreak of the information technology revolution, and it is also an important component of digital methods. The number of indoor space models created through computer-aided computing systems is directly related to the number of constraint conditions. If the designer establishes fewer constraints, the number of computer-generated indoor space models will be very large. On the contrary, if the designer establishes more constraints, the number of computer-generated spatial models will decrease. Entezari et al. [6] concluded that the number of constraints is inversely proportional to the number of indoor space models. And no matter how designers try their best to establish more constraints, the final number of indoor space models is still very large.

Felek [7] proposed a sailboat model that includes parameter-based external modeling and an internal design layout. In the field of yacht design, geometric software has become a powerful assistant for designers. Compared with traditional hand-drawn design plans, this three-dimensional display method undoubtedly provides designers with a more comprehensive and accurate visual experience. Especially in engineering calculations, this software can accurately process various complex data and algorithms, ensuring the accuracy and reliability of the design. These software typically have powerful 3D viewing capabilities, allowing designers to observe the shape of ships from multiple angles on the screen, thereby gaining a more intuitive understanding of their overall shape. When creating a yacht model, it is necessary to fully consider the design elements of the yacht type. These elements not only affect the appearance style of the yacht, but also directly affect its performance and user experience. The design process begins, and the modifications made to the model will also be previewed as the variables change. The indoor space of commercial buildings is closely connected to the overall building, like a harmonious symphony, with each part echoing each other, creating a unique and complete place experience together. The arched market is an outstanding example of this. The clever design of MVRDV architecture firm not only complements the overall architectural form of this commercial space, but also takes a unique approach to interior interface design. Integrating multi-objective optimization algorithms with parametric design and integrated simulation to achieve comprehensive optimization of interior design parameters. Cleverly integrating the selling elements of the market and echoing the distant church environment, creating a sense of place with rich regional characteristics. It deeply considers the overall shape, surface, texture, and color of the building, as well as its dialogue with the surrounding environment. The graphic design of walls and ceilings, and the interaction between users and interface forms, have become a crucial part of the design. Visual perception, as the main way of perception, profoundly affects the user's judgment of spatial sense. This kind of interaction not only helps to improve the unreasonable factors in the space, but also enhances the self-clarity of spatial functions by shielding and protecting auxiliary spaces, and creates a unique spatial atmosphere. By combining multi-objective optimization algorithms with parametric design and integrated simulation, we can more systematically explore the relationships between various design parameters, find the optimal design solution, and thus achieve comprehensive optimization of interior design [8].

The appropriate application of spatial interface materials plays a crucial role in the depiction of commercial scenes. Through appropriate material application and visual perception guidance, we can create a rich diverse, captivating commercial space experience. This presentation method is not only more vivid and multi-dimensional but also can trigger the experiencer's association with material knowledge, producing a tactile experience effect. In the process of interactive design, in-depth analysis of the impact of material changes on user visual perception can cleverly complete the design intention, demonstrating its unique characteristics and advantages. This interactive way of visual perception and material association plays an undeniable role in design. A clearer texture or high pixel material presents the delicate changes of the material in a realistic way under light and shadow. The material display of virtual scene interfaces is more vivid and comprehensive than renderings or physical interface material samples, providing broader design ideas and possibilities for the creation of commercial spaces. Taking the indoor display of a wooden decorated restaurant as an example, we used modeling software Sketching Master to construct a preliminary model and conducted detailed rendering using virtual reality technology. This design approach not only enhances the visual beauty of the space, but also enhances the emotional connection between the user and the space through the association of material touch.

2 RELATED WORKS

With the continuous advancement of computer technology, parametric modeling has been widely applied in various fields. In the interior design industry, the application of parametric modeling makes interior design faster, more convenient, and more accurate. With the continuous increase in demand for commercial housing, the demand for interior design is also on the rise. However, the cumbersome operations and complex processes of interior design software limit the use of the general public, resulting in the final effect of interior design deviating from the initial idea. With the popularization and gradual improvement of mobile phones, many types of production software can be used on mobile apps, and the parameterized design of indoor spaces can also be based on mobile apps, providing users with simpler and more practical ways of use. Han et al. [9] focused on the parametric design of indoor spaces on mobile devices. By studying the basic concepts, development status, technical characteristics, usage methods, and practical value of parameterized design for indoor spaces on mobile devices. And envision and design the possibility of parameterized indoor space design on mobile devices in terms of functional use. Its intention is to explore and explore the possibility of parameterized design of indoor spaces for use on mobile devices.

Lee et al. [10] selected a residential building in Chengdu as the basic physical model, considering indoor comfortable wind speed area ratio, indoor average air temperature, temperature non-uniformity coefficient, and average air age as ventilation effectiveness evaluation indicators. It uses orthogonal design and Fluent numerical simulation methods to explore the indoor natural ventilation effects of different outdoor and indoor building design parameters under different combination conditions. In order to verify the reliability of the numerical model and confirm the relevant parameter settings of the basic model, a comparative analysis was conducted between on-site measured data and simulation results data. The results indicate that the indoor temperature and velocity trends are consistent, with acceptable errors. The basic model settings are reliable and can be used to predict the distribution of temperature and velocity fields in naturally ventilated rooms. Many design software has emerged, greatly improving work efficiency. Tytarenko et al. [11] used digital tools to perform 3D modeling of virtual building environments. In the field of 3D modeling, tools such as CAD, 3DMax, Rhino, Blender, C4D, etc. are gradually becoming comprehensive mainstream tools. This approach not only provides more possibilities for building space, but also enables data analysis during the spatial construction process, thereby improving design efficiency and level. Parametric modeling is widely used in various fields, such as architecture, industry, sculpture, furniture, video game effects, and medical 3D printing. In the field of indoor residential space design, the application of parameterization has improved the efficiency of building spaces. It also concretely describes the effect of designing objects in virtual space, enabling people to construct future things faster and more accurately. However, the software usage technology for parameterized space design is in the hands of a few designers, as it requires the use of powerful computer configuration, software application technology, and aesthetic level. However, the public can only obtain interior design renderings by encouraging designers to perform a series of operations through transactions.

Wu et al. [12] studied the information modeling method of building model parameters in the Revit environment. In order to achieve efficient construction and management of 3D models, Revit software was chosen as the parametric modeling environment. Using Dynamo as a development tool, combined with Python language, research on rapid modeling methods for digital twin systems. At the same time, it also studied the information virtual real interaction method under the digital twin system. Due to the truncation problem in the interaction between real space and digital space in digital twin systems. In order to ensure data-driven fluency, based on the OPCUA architecture, we use physical space data to drive the model of digital space, and study the construction of communication methods between digital space and real space. Due to the different specific conditions of each indoor space, as well as the varying environmental factors, geographical conditions, and functionality of the indoor space, it can lead to significant differences in the constraints summarized by parametric design methods. So after conducting computer-aided calculations, for each indoor space with different design requirements, its shape will vary greatly [13]. From this, it can be concluded that the modeling styles of parameterized interior space design are endless. No two indoor spaces created using parametric design methods are the same, and no type of indoor space shape will repeat itself in the next parametric indoor space design.

Yi [14] studied a lightweight loading method for 3D models on online platforms. Due to the unfavorable structure of Revit models for easy viewing, the loading time on the network platform is relatively long. In order to achieve fast loading and smooth display of data models on online platforms, based on Revit models, secondary development of Revit interfaces and research on lightweight 3D model technology based on the octree algorithm are carried out. It applies the above methods to the 3D visualization system of intelligent buildings. Implemented functions such as asset inspection, rapid equipment positioning, system shelling, equipment maintenance, and asset inventory for building information. The experimental results indicate that the research plan and core technologies of the paper have good feasibility and effectiveness. Zou et al. [15] proposed an innovative parameterized design, layout, and virtual simulation method for construction machinery. This method utilizes the Unity3D platform to simulate construction machinery in a virtual scene. Through the Unity simulation platform, construction personnel can also receive pre-shift education, simulate construction machinery operations, and improve operational proficiency and accuracy. Compared with traditional design patterns, this new design method not only has better visualization effects, but also makes the design scheme more intuitive and understandable. This method fully utilizes Blender open-source software and its powerful visualization programming tool Geometry Nodes (GN). Accurate parameterization and rapid modeling of construction machinery have been achieved. This not only improves the accuracy of the design, but also greatly shortens the design cycle. This virtual simulation method enables construction personnel to have a deep understanding of the performance and operation of construction machinery before actual construction, thereby effectively improving the safety of construction.

3 PARAMETRIC MODELING AND PLATFORM DEVELOPMENT

3.1 CAD-Assisted Parametric Modeling

CAD-assisted parametric modeling is a method of modeling using computer-aided design software, and its core idea is to abstract various elements in the design into adjustable parameters, such as size, shape, material, etc., so as to realize rapid, flexible, and precise adjustment and modification of the design scheme. CAD-assisted parametric modeling is widely used in the creation and optimization of design solutions. Designers can adjust parameters, such as room dimensions, furniture layouts, lighting settings, etc., according to customer needs and spatial requirements to realize diverse design exploration and comparison.

This not only reduces computational complexity but also markedly enhances the accuracy of predictive calculations for selecting colors in interior design materials. Figure 1 shows the image difference prediction algorithm and color component results.

The traditional image difference method enables the prediction of neighboring color pixels.

$$l=\frac{x+y}{2},h=x-y \tag{1}$$

Equation (1) can be obtained by performing integer wavelet inverse transform:

$$\begin{cases} x=l+\frac{h+1}{2},y=l-\frac{h}{2} \middle| h\geq 0 \\ x=l+\frac{h}{2},y=l-\frac{h-1}{2} \middle| h<0 \end{cases} \tag{2}$$

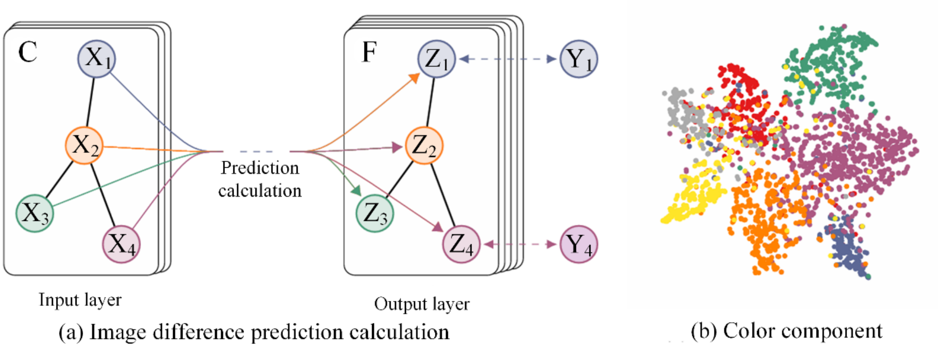

Figure 1: Image difference prediction algorithm and color components.

The difference of one pixel is then embedded in Eq. to obtain the difference extended prediction formula:

$$h_w = 2h + w \tag{3}$$

In the process of interior design, there is a subtle correlation between the pixels of the selected colors, which is not only powerful but also has a profound logical foundation. This means that when we try to predict the color of a pixel, the information provided by adjacent pixels is more accurate and reliable than pixels that are farther apart. Subsequently, we will identify other pixels around this pixel and predict the color of the central pixel by analyzing these adjacent pixels. This correlation is the cornerstone of predicting and linearly compressing colors, enabling us to manipulate and predict colors more accurately.

$$p_w = 2p + w \tag{4}$$

The value of the predicted pixel is:

$$a_w = \bar{a} + p_w \tag{5}$$

Based on the principle of color tone triangle, RGB components are independent of each other. In order to improve the accuracy of image parameterization and fully utilize the strong correlation between adjacent pixels. We choose the pixels around the pixels to be parameterized as the baseline. Through this approach, we can closely link the color information of surrounding pixels with the central pixel, thereby further improving the accuracy of parameterization. This average not only reflects the overall trend of surrounding pixel colors, but also weakens the impact of possible outliers in a single pixel on the prediction results. In summary, by selecting adjacent pixels as benchmarks and calculating their average values, we can fully utilize the correlation between pixels, improve the accuracy of image parameterization, and provide a more scientific and reliable basis for the selection and matching of interior colors.

$$\bar{S} = \frac{1}{4} \times \begin{vmatrix} & 1 & \\ 1 & \bullet & 1 \\ & 1 & \end{vmatrix} \tag{6}$$

$$l = \frac{p_1 + p_2}{2}, h = p_1 - p_2 \tag{7}$$

$$\begin{cases} p_1 = l + \frac{h+1}{2}, p_2 = l - \frac{h}{2} & \left| l \geq 0, h \geq 0 \right. \\ p_1 = l + \frac{h}{2}, p_2 = l - \frac{h-1}{2} & \left| l \geq 0, h < 0 \right. \\ p_1 = l + \frac{h}{2}, p_2 = l - \frac{h+1}{2} & \left| l < 0, h \geq 0 \right. \\ p_1 = l + \frac{h-1}{2}, p_2 = l - \frac{h}{2} & \left| l < 0, h < 0 \right. \end{cases} \tag{8}$$

$$h_w = (p_1 + p_2)\sqrt{2h + w} \tag{9}$$

$$a = \frac{(p_1 + p_2)^2 + (p_1 - p_2)^2}{2}, h = 2\sqrt{(p_1 + p_2)^2 + (p_1 - p_2)^2} \tag{10}$$

$$\begin{cases} p_1 = l \pm \frac{h+1}{2}, p_2 = p_2 \pm \frac{h}{2} & \left| a \geq 0, h \geq 0 \right. \\ p_1 = l \pm \frac{h}{2}, p_2 = p_2 \pm \frac{h-1}{2} & \left| a \geq 0, h < 0 \right. \end{cases} \tag{11}$$

$$\begin{cases} p_1 = l \pm \frac{h}{2}, p_2 = p_2 \pm \frac{h+1}{2} & \left| a < 0, h \geq 0 \right. \\ p_1 = l \pm \frac{h-1}{2}, p_2 = p_2 \pm \frac{h}{2} & \left| a < 0, h < 0 \right. \end{cases} \tag{12}$$

Within this range, the color components of any pixel to be predicted are derived, taking into account the error derived above, to finally obtain a parametric model for the difference of color images of interior design materials.

$$\begin{cases} \left| p_{nw} \right| = \left| p_n \right| - 1 & \left| p_n > T_n \right. \\ p_{nw} = p_n + 1 & \left| \bar{a} < 128, p_n < T_n \right. \\ p_{nw} = p_n - 1 & \left| \bar{a} \geq 128, p_n < T_n \right. \end{cases} \tag{13}$$

3.2 Visualization Teaching Platform

Visualization teaching platform is a kind of teaching tool that uses computer technology and virtual reality technology to present the learning content to the user in a visualized form. It can combine images, videos, animations and other media forms to help students understand abstract concepts and complex theories more intuitively, and improve the learning effect and learning interest. In the field of interior design, the visual teaching platform can help students better understand design elements such as space layout, color matching, furniture arrangement, etc., and improve their design ability and creativity. Through the platform, students can experience the effect of the design scheme in the virtual environment and feel the atmosphere of the space and the influence of the layout so as to deepen their understanding of the design concept. VR equipment can bring students into the virtual three-dimensional space so that they feel as if they were in the design scheme and feel and adjust the design effect in real-time. Through head-mounted displays and handheld controllers, students can move and operate freely in the virtual environment, interact with the design program, and improve their immersion and participation in learning.

Figure 2 shows the world's first VR device, Sensorama Simulator, and PlayStation VR2 device. Overall, the visualization teaching platform combines the advantages of computer technology and virtual reality technology to provide interior design education with new teaching methods and learning experiences. Through the platform, students can understand design concepts and technologies more intuitively, improve design ability and creativity, and lay a good foundation for the training of future interior designers. Therefore, this experiment chooses PlayStation VR2 to be the hardware support device to visualize the teaching.

Figure 2: World's first VR device, Sensorama Simulator and PlayStation VR2 device.

4 INTERIOR DESIGN AND TEACHING PLATFORM APPLICATIONS

In order to validate the performance of the parametric model of interior design established in this study, this experiment started a field project with a design firm to obtain feasibility and scientific judgment. After months of screening and negotiation, this experiment identified a home as the experimental subject. After fully communicating with the homeowner, this experiment conducted field measurements and collected the necessary data. Then, this experiment imported these data into the established parametric model for processing and analysis. Eventually, this experiment used the CAD-assisted model to generate the design rendering, as shown in Figure 3 below.

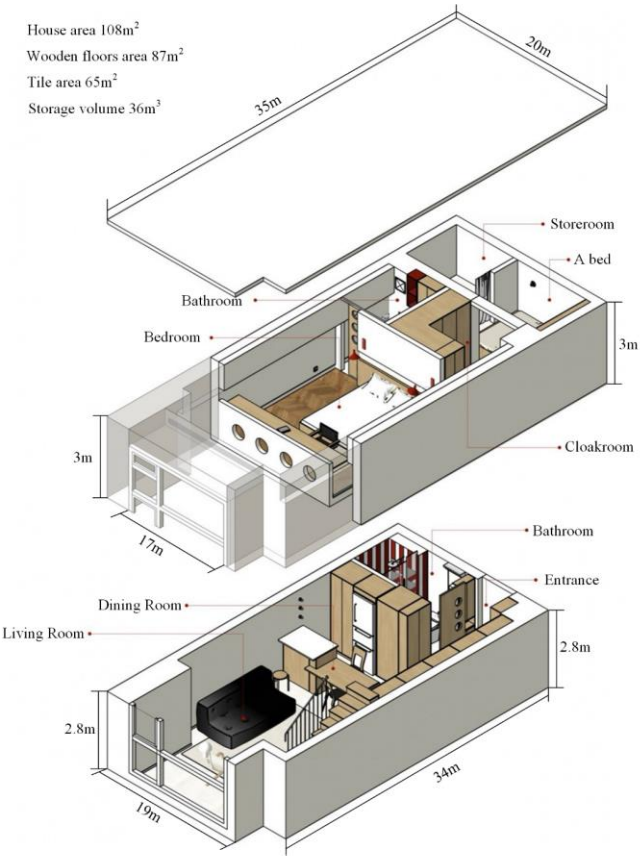

Figure 3: CAD-assisted modeling of the production of interior decorating effects.

Through this experiment, the effect of parametric modeling in real projects can be visualized. The communication with the owners makes this experiment better understand their needs and preferences, and the field measurement data provides accurate basic information for this experiment. Then, through the effect diagrams generated by CAD-assisted modeling, this experiment can clearly show the specific effect of the design scheme, thus providing an intuitive and feasible reference for the owners, as well as strong practical support for this study. The close cooperation of this experiment not only verifies the feasibility and scientificity of the parametric model established in this study, but also provides valuable experience and inspiration for future research. This experiment believes that with such cooperation, the results of this study will be able to be better applied to practical projects and make greater contributions to the development of the interior design field.

After designing the effect diagram, with the assistance of a VR device, the diagram can be visualized more three-dimensionally. When utilizing the VR device to display the effect diagram, the parameters that need to be paid attention to and adjusted are as follows. The first is the adjustment of the viewing angle and viewpoint. In the VR environment, the user's viewing angle and viewpoint will directly affect their perception and understanding of the design scheme. Therefore, the viewing angle and viewpoint of the VR device need to be adjusted to ensure that users can fully observe the design effect from different angles and positions. Next is the control of scale and size. When converting a design solution into a VR environment, it is necessary to ensure that the proportions and dimensions of the design elements match the actual situation in order to maintain the authenticity and credibility of the design. By adjusting the proportion and size parameters, it can be ensured that the design effect in the VR environment is consistent with the actual space. Then comes the lighting and shadow settings. Lighting and shadows are important factors that affect the design effect, and are especially important in VR environments. By adjusting the lighting and shadow settings, the three-dimensionality and realism of the design effect can be enhanced so that users can better feel the atmosphere and layout of the space. In addition, interactivity and operation modes need to be considered. In a VR environment, users can usually interact and operate through handheld controllers or head-mounted devices. Therefore, it is necessary to design appropriate interaction interfaces and operation modes so that users can easily navigate and adjust the design scheme to improve user experience and participation. Finally, animation and effect display. Using the VR environment, a more vivid and intuitive animation and effect display can be realized. By adding dynamic effects and interactive elements, it can attract users' attention and enhance their understanding and perception of the design scheme. By paying attention to and adjusting the above parameters, with the assistance of VR devices, the design rendering can be made more vivid, three-dimensional and intuitive, providing users with a better experience and sense of participation.

When exploring screenshots of VR display devices, we selected a circular area with a specific radius of R for analysis. In order to fully utilize this information, we adopted an image difference prediction model, which can generate 2n unique patterns based on these sampling points. In this context, we introduce the concept of dynamic equivalence patterns. According to this mode, when a circular binary number is converted between 0 and 1 no more than two times. The area contains n key sampling points. These sampling points provide us with rich information about image details. Its corresponding binary is considered to belong to the same equivalent pattern class. This method allows us to reduce the dimensionality of the data more effectively. This not only significantly reduces the complexity of the data, but also helps to remove the interference of high-frequency noise, making the final obtained feature vectors more concise and effective. Through such processing, we can not only process and analyze image data more efficiently, but also improve display accuracy. This provides strong support for our research and application in VR display devices, and also provides new ideas and methods for us to further explore the fields of image processing and pattern recognition.

Figure 4 shows four modes of color pixel acquisition points in the effect map after dynamic equivalent mode dimensionality reduction. In VR technology, the display of images follows the general rules of color, and one important factor is the saturation of the color. Saturation refers to the proportion of gray components contained in a color, the color is more grey in the user's visual perception. By adjusting the saturation of a color, you can affect the color performance of the picture.

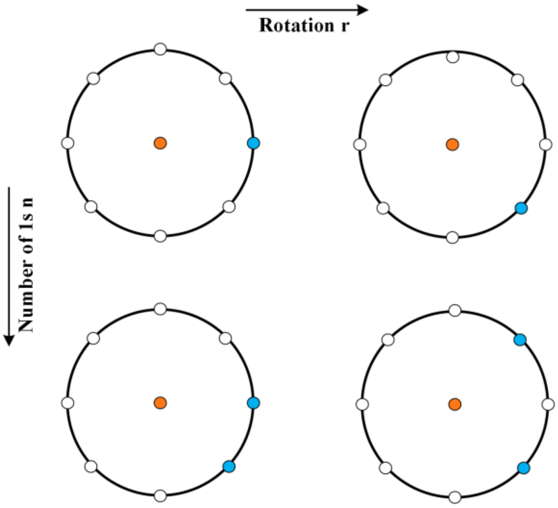

Figure 4: Four modes of color pixel collection points of the effect map after dimensionality reduction of the dynamic equivalent mode.

Lower saturation will make the color look lighter and softer while reducing the intensity of the color. Conversely, higher saturation makes colors more vibrant and full, with more impact and vividness. This adjustment in color saturation not only affects the visual appearance of the image but also has an impact on the user's experience. Low saturation colors may give a quiet, introspective feeling, suitable for creating a soft atmosphere or emphasizing the stability of the picture, while high saturation colors can attract the user's attention and enhance the visual impact and vitality of the picture.

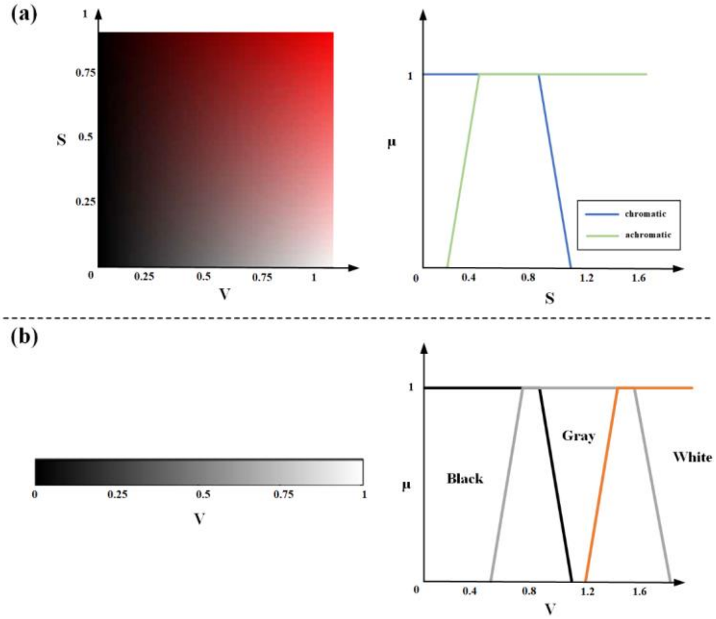

Figure 5: Color perception component in VR technology.

In the left panel of Figure 5(a), we can clearly see that when the saturation is adjusted to 0, the brightness is also close to the minimum value. The color change near the horizontal axis gradually transitions from dark black to gray. When the saturation remains at 0, and the color tone also approaches 0, the brightness gradually increases. The color tone change at this time has minimal visual impact. This change process indicates that only when the changes in saturation, tone, and brightness reach an appropriate balance and interval can humans understand and distinguish colors according to traditional color perception methods. The left panel of Figure 5(b) shows another scenario where the change in brightness becomes a key factor dominating the visual experience when both saturation and color values are set to their lowest. Trapezoidal blur not only enhances the sense of hierarchy in the image but also makes color transitions more harmonious. The grayscale transition in the image is smoother and more natural, as shown in the image on the right in the above image. As the normalized range of brightness changes continuously from 0 to 1, the color gradually transitions from dark black to gray and finally turns white, forming a complete brightness gradient band. This changing pattern makes us realize that for human visual perception, the most intuitive difference between non-colors (i.e., grayscale) is the change in brightness.

In VR display, noise is a common problem that leads to blurring of the image, and its appearance will affect the user's viewing experience. Therefore, this experiment pays attention to this problem and takes measures to denoise it. Denoising is a process of suppressing or eliminating the noise signals in an image through algorithms or processing techniques to improve the clarity and quality of the image. In this experiment, the corresponding denoising method is adopted to deal with the noise problem in the VR display, and the picture is processed. After the denoising process, the clarity and details of the picture are effectively improved, the noise is obviously reduced, and the picture is clearer and more realistic. In order to show the denoising effect more intuitively, this experiment compares the picture before and after processing, and the local results are shown in Figure 6.

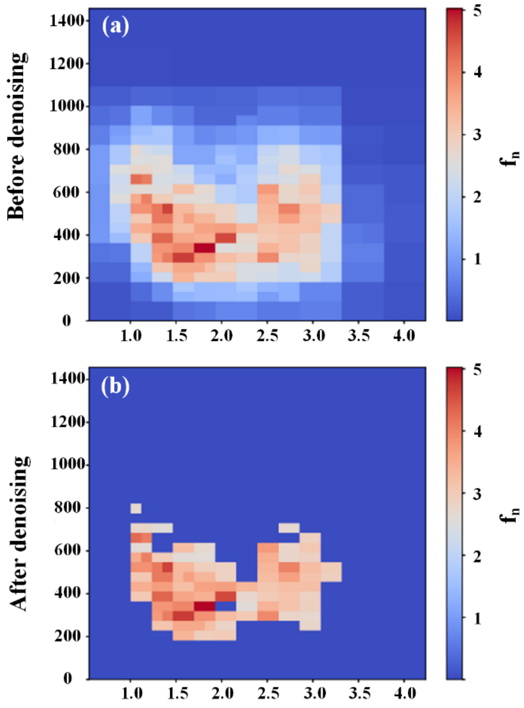

Figure 6: Comparison of localized images before and after denoising.

By comparing the local results in Figure 6, it can be clearly seen that after the denoising process, the details of the picture are clearer, the noise is significantly reduced, and the overall picture is clearer and more realistic. This shows that the denoising process has a significant effect in improving the quality of the VR display screen, which can improve the user's viewing experience and make them more immersed in the virtual environment. Therefore, for the noise problem in VR display, the denoising method adopted in this experiment provides an effective technical means to solve such problems, and makes an important contribution to improving the quality of VR display screen and user experience.

Finally, after several months of construction, this study, in conjunction with a design firm, was finalized with VR equipment to show the results to the owners. Some of the interior room designs and decorative effects are shown in Figure 7 below.

Figure 7: CAD-assisted parametric model of interior design results of the actual installation.

In Figure 7, Figure 7(a) shows the design result of the living room, Figure 7(b) shows the dining room, Figure 7(c) shows the kitchen, and Figure 7(d) shows the bedroom. Compared with the CAD renderings, these actual fitting results have the same overall style, and the design concept is maintained. However, after the optimization of the visualization platform, the actual fitting results are more delicate and warmer than the renderings. This demonstrates the effectiveness and usefulness of the model developed in this study in practice. By collaborating with the design office and utilizing VR equipment to display the design effect, the owner can understand the design scheme more intuitively and feel the atmosphere and layout of the interior space in advance. This intuitive communication helps to reduce misunderstandings and unnecessary modifications and improves the efficiency and quality of the execution of the design scheme.

5 SUMMARY

The experiments and explorations in this study enabled a deeper understanding of the application and development of CAD-assisted parametric modeling and visualization teaching platforms for interior design. Making the creation and adjustment of design solutions easier and more accurate. Through the use of algorithms based on image difference prediction, the design effect can be more accurately predicted and adjusted, thus improving the scientific and practicality of the design. Secondly, the visualization teaching platform combined. Through virtual reality technology, students can experience the design scheme immersively, deepen their understanding of the design concept, and enhance their design ability through real-time interaction and adjustment. On this basis, VR equipment has been introduced to further enhance the effect of the visualization teaching platform, providing students with a more intuitive and in-depth learning experience. Finally, by cooperating with the design office and using the VR equipment to show the design effect to the owner, we verified the effectiveness and practicality of the parametric model established in this study in practice. After the field construction and debugging, the real installation effect demonstrates the great potential and application prospect of CAD-assisted parametric modeling and visualization teaching platform. In summary, the development of CAD-assisted parametric modeling and visualization teaching platforms for interior design will bring more innovations and possibilities to the field of interior design, provide more powerful tools and platforms for designers and students, and promote the continuous progress of interior design education and practice.

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